Role of ARPA-E in Accelerating Fusion Energy

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ARPA-E Mission

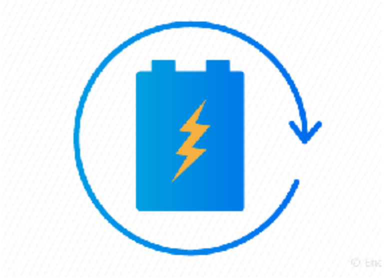
Goal 1: To enhance the economic and energy security of the U.S. through the development of energy technologies that—

- REDUCE IMPORTS
- IMPROVE EFFICIENCY
- REDUCE EMISSIONS
- IMPROVE THE MANAGEMENT, CLEAN-UP, AND DISPOSAL OF RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL
- IMPROVE THE RESILIENCE, RELIABILITY, AND SECURITY OF ENERGY INFRASTRUCTURE

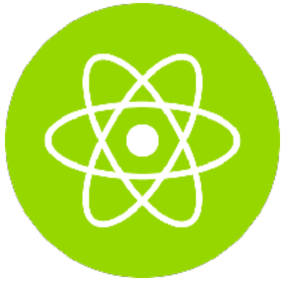
Goal 2: To ensure that the U.S. maintains a technological lead in developing and deploying advanced energy technologies.

Framing of fusion energy within ARPA-E's portfolio

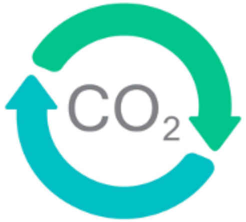
- Fusion samples the **highest-risk and highest-impact end of ARPA-E's portfolio,** with potential to be:
  - A safe, abundant, firm, zero-carbon-emitting source of primary energy, electricity, heat
  - Dispatchable
  - Sited near population centers
- ≤ 2050: **Enable fusion** as a risk-mitigation option for meeting net-zero targets



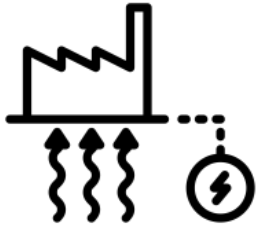
Renewables + long-duration storage



Advanced nuclear fission

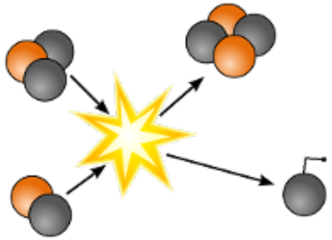


Fossil w/ CCUS



Enhanced geothermal

Biofuels



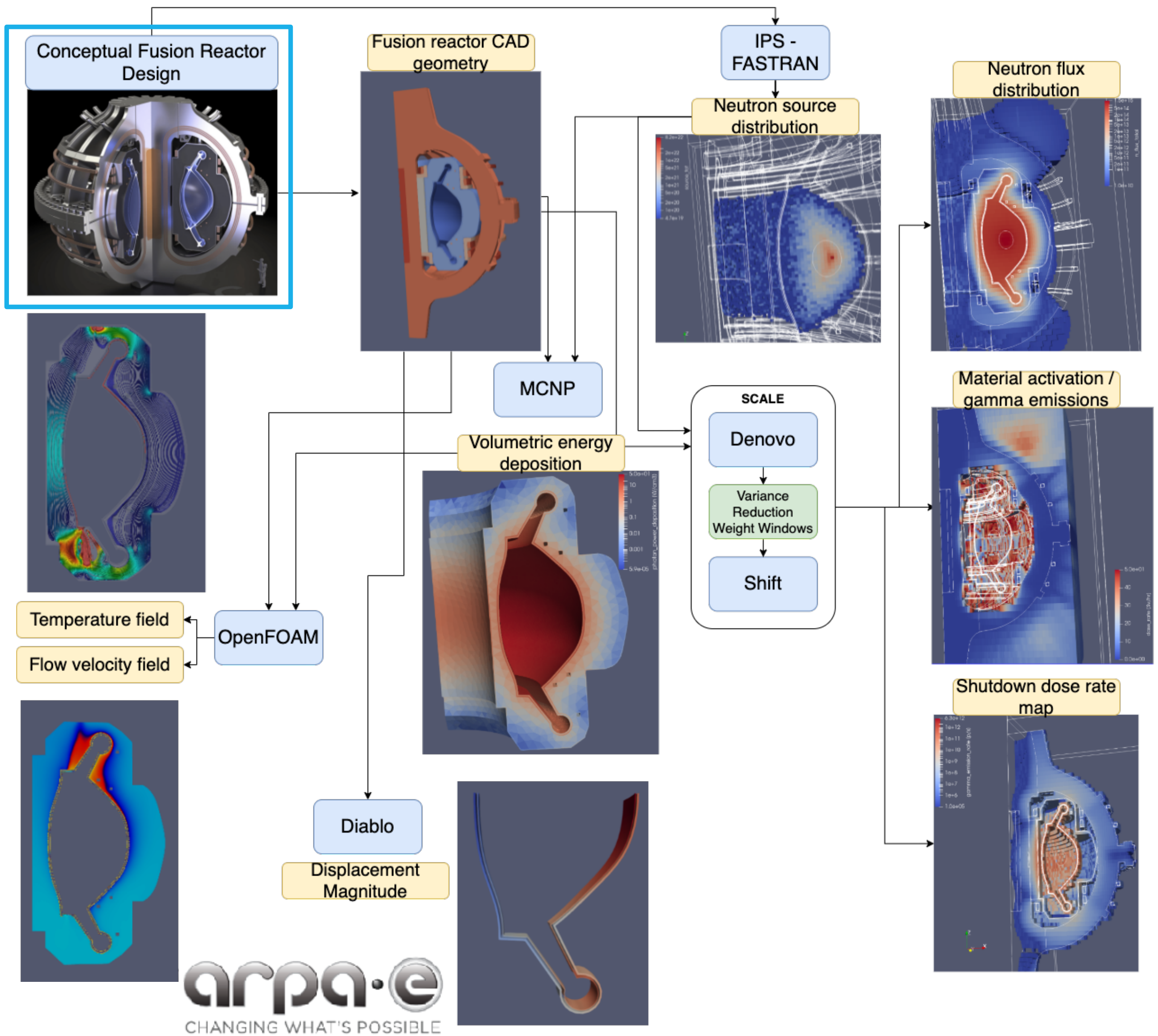
\+ Fusion

- Beyond 2050: Fusion energy could provide sustainable flexibility for zero-carbon energy

ARPA-E impact on commercial fusion R&D

- ARPA-E's fusion programs helped forge a dramatically changed fusion R&D landscape over the past 7 years
  - **$780M (and growing) of private funding as a result of ARPA-E fusion awards**
  - Focus on capital cost and projected levelized cost of electricity (LCOE)
- New (MIF) and renewed (MFE/IFE) investigations of promising fusion concepts
  - Enabling materials & technologies R&D focused on multiple, commercially oriented concepts
- From one (ITER) to multiple development paths (CFS, CTFusion, Helion, HyperJet, Realta, Type One, Zap, etc.)
  - 6 new fusion companies from ARPA-E programs so far
- Broad engagement with commercialization stakeholders

Fusion Energy Reactor Models Integrator (FERMI)



PI: Vittorio Badalassi

Team: ORNL, LLNL, CFS, MIT, Hypercomp, NVidia

ARPA-E GAMOW Award

Technology Summary

- *Development of a virtual reactor*
- *Integrated plasma physics, PMI, shielding, structural/ thermal, MHD, fluids, UQ models*
- *Validation on available data and results*

Technology Impact

- Speeds up the overall design development by 30 times
- Exceptional fidelity of the engineering calculations
- Enables the development of a commercial fusion reactor

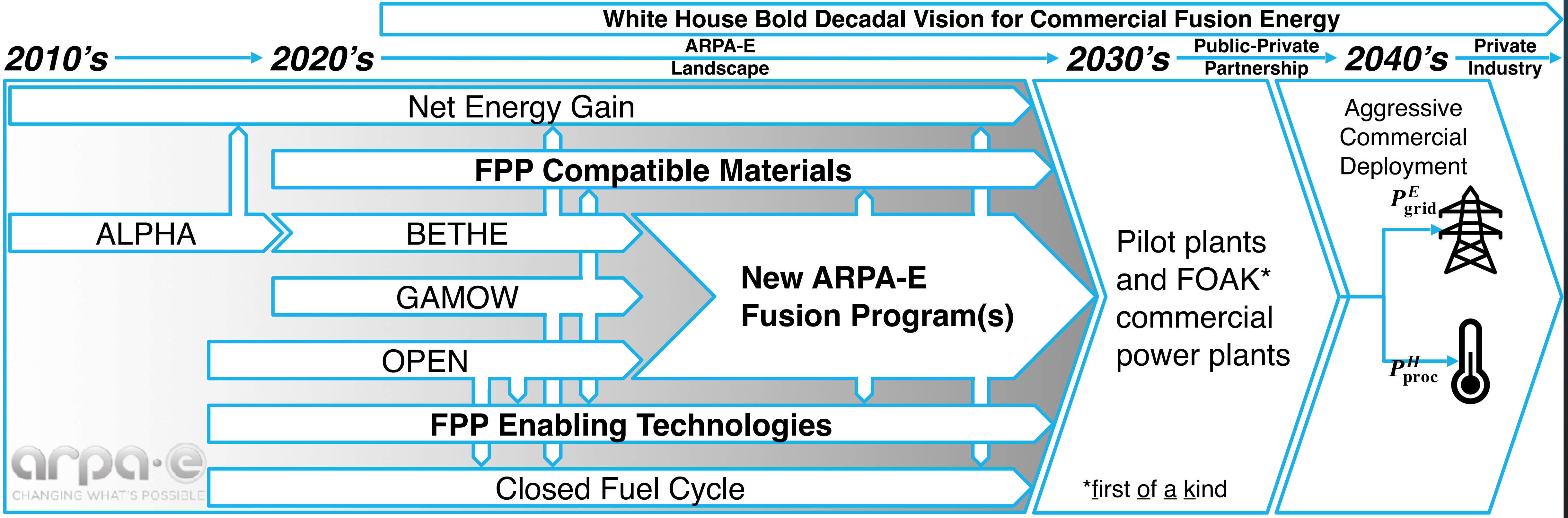
Proposed Targets

Metric	State of the Art	Proposed
Coupled Multiphysics First Wall and Blanket Simulation	*No existing capability*	*FERMI integrated simulation environment*
FliBe cooled/breed FW & Blanket Proof of Concept	*TRL = 3*	*TRL = 6*
Conceptual Design time	*9 Years*	*3 months*
Design team number and design iterations	*20 engineers and 3 iterations*	*3 engineers and 6 iterations*

What is needed for a fusion power plant (FPP)

- **Net energy gain**
  - A high-performance plasma is at the center of any potential FPP
- **FPP compatible materials**
  - Robust materials are essential, needing a dedicated and FPP relevant neutron source for validation and development
- **FPP enabling technologies**
  - Increase attractiveness of FPPs by increasing plant efficiency and availability, reducing the cost and operational complexity
- **Closed fuel cycle**
  - Tritium self-sufficiency is a key requirement for the first commercial FPPs

- **White House bold decadal vision will lay groundwork for commercialization, *including* energy justice**



Vision for next ARPA-E fusion programs should leverage…

- **Surge in private investment in fusion energy**
  - Emphasizes near-term success/ROI with higher risk and multiple concepts
- **Technological advances in fusion subsystems (e.g., drivers, heating)**
  - Push for compactness presents new/different challenges
  - New technologies (simplified maintenance schemes) and design methodology (disposable core internals) may alter requirements and increase performance
- **Advances in the materials science towards fusion**
  - Advances in theory, computation, and modeling capabilities (including AI/ML) and material synthesis offer opportunities for accelerated material discovery
- **Advances in testing, irradiation (ion beam, proton, fission) and characterization capabilities**

Enabling technologies for improving fusion power plant performance and availability

RFI closed on November 28th

Low-cost commercial fusion energy

A

Improving performance with innovative heating schemes and high-performance targets

Advanced driver technologies and target-driver architectures

Microwave heating (e.g., high-power, long-pulse microwave sources with electrical efficiency ≥ 55%)

Neutral particle beam heating challenges (e.g., novel neutral beam approaches; negative ion beam system with electrical efficiency > 60%)

- Low-cost scalable high rep-rate laser drivers for inertial fusion
- Reproducible target design and delivery systems at few Hz
- Optics technology with higher damage threshold tolerance to optics damage (gas optics, etc.)

B

Increasing FPP availability through accelerated discovery of novel fusion materials

Materials "by design" for plasma facing components and for enabling high-throughput tritium handling

Solid & self-healing materials with the following features

- minimize half-lives of materials
- reduce dust formation
- minimize fuel retention (e.g., hydrogen)
- minimize the displacement per atom due to neutron irradiations
- high heat resistant (> 600 C)
- corrosion resistant

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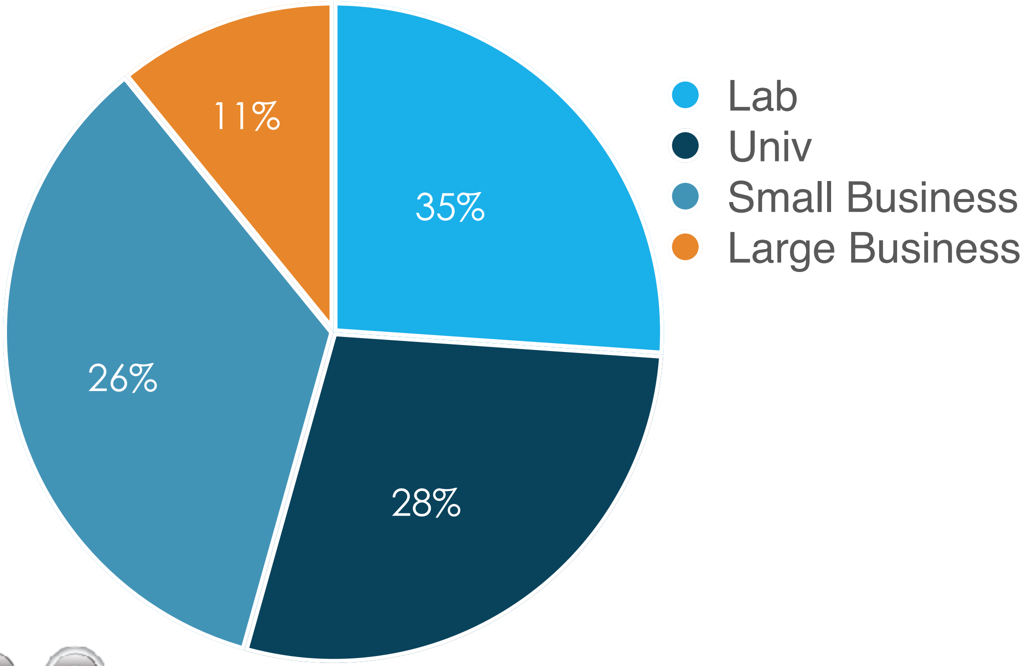
CHANGING WHAT'S POSSIBLE

RFI responses are being processed

- Many good responses *with novel ideas and insights* on next generation fusion materials and enabling technologies
  - 46 responses received (2 – 15 pages each) in a 5-week timeframe
- Stay tuned for possible workshop and next steps

Breakdown of Respondents:



THANKS!

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